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The Regional Municipality
of
Hamilton Wentworth

Farebox Performance Assessment

Hamilton Street Railway



RGP
TRANSTECH
INC.

September, 1987

URBAN MUNICIPAL

OCT 10 1987

GOVERNMENT DOCUMENTS



CONSULTANTS
IN
TRANSPORTATION

MISSISSAUGA
2000 Argentia Road
Plaza One Suite 201
L5N 1P7
(416) 821-1255

HAMILTON
1400 Rymal Road East
L0R 1P0
(416) 385-3234

ADDENDUM TO
FAREBOX PERFORMANCE ASSESSMENT REPORT

Page 1-1 , paragraph two: old fareboxes in use 42 years

Page 7-1 , Farebox Jamming: coin motor automatically
activates to clear jam

Transtech Inc. September 1987

FAREBOX PERFORMANCE ASSESSMENT
HAMILTON STREET RAILWAY

RGP Transtech Inc.
Mississauga

September, 1987
Hamilton



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1.0 INTRODUCTION

The Hamilton Street Railway (HSR) acquired Cubic Western Electronic Self Registering Fareboxes for their fleet of 256 buses. The fareboxes were introduced systemwide on March 14, 1987. The fareboxes are capable of identifying coins of various denomination, bills and tickets. The deposited amount is automatically totalled and the total is displayed. Future hardware can be added to the farebox in the form of a pass reader.

The HSR required the new fareboxes on the basis that their old fareboxes were 24 years old and were outdated. Because of the age and condition of the old fareboxes and because of the wide use of dollar bills as a fare, the incidence of fare jams and fare disputes was rising. There was also a suspicion that fare evasion was beginning to occur and this was cutting into revenue. It was felt that the new fareboxes would be competitive with the old fareboxes in terms of passenger boarding times and farebox maintenance effort. It was also anticipated that the driver and public acceptance of the new fareboxes would be good. Calculations made by the HSR indicated that a payback period of 7.5 years on capital would occur.

An evaluation program was developed to determine how well the new farebox performed certain functions mentioned above. First, an analysis of HSR Road Call Reports was undertaken for the first fourteen weeks of operation of the fareboxes. The Road Call Reports identified the number of problems and their causes for farebox related incidents on the road. Among other things, this related to fare jams. Second, an analysis of the first fifteen weeks maintenance records were undertaken to identify the type, frequency and maintenance time required to repair various components of

the farebox. After some adjustments to procedures and hardware, maintenance records from week 20 through week 24 were examined. Third, an investigation was made to determine the amount of fare evasion in the system and how much the new farebox collected over the old fareboxes. The fare evasion investigation was based on a before and after study of fares collected using the old and new fareboxes. Fourth, a Driver Survey was conducted to determine driver acceptance and opinion of the new farebox, including the incidence of fare disputes. Fifth, boarding time information was collected and analysed to identify the effect of the new fareboxes on boarding time.

The results of the evaluation programs were compared with the projected results of savings identified in the HSR letter of the Ministry of Transportation and Communications dated March 4, 1986.

2.0 ROAD CALL EVALUATION

The Road Call Reports were filled out each time an inspector responded to a call from a driver for farebox assistance. The Road Call Report was used to record response and repair time, as well as the initial problem and its probable cause. The inspectors have access to the fareboxes and can replace coin and bill modules, clear jams, reset power switches and reset fareboxes. Over the fourteen week period, for which Road Call Reports were analysed, a total of approximately 740 individual reports were reviewed.

The Road Call Reports provided a record of the number of road calls made by inspectors each week and provide information on the amount of time spent weekly by inspectors on response and repair time for fareboxes and farebox calls. The basic farebox problems described on the Road Call Reports related to coin modules, bill modules, clear and reset, other problems or as an unresolvable problem requiring the bus to be pulled out of service. For each problem addressed, the inspectors were able to indicate whether, in their opinion, the problem was caused by a jam, mechanical or electrical problem, power failure, passenger or driver induced problem, incorrect codes in the farebox or "other".

Table 1 summarizes the HSR Road Call Assessment. There were 184 road calls in the first week that the farebox was in use, 67 each in the second and third week, and the number of calls had dropped to between 25 and 35 by the last two weeks of the analysis period. This pattern represents a typical learning period. It is anticipated that the end of period rate of 25 to 35 road calls weekly will continue to be experienced. Table 1 also

shows the amount of time devoted to road calls by the inspectors. The first week required almost 42 man hours (2512 minutes), the second and third week each averaged about 17 man hours and by the final three weeks of the assessment period, the weekly effort had stabilized at about eight man hours.

Most of the problems that the inspectors had to resolve in the field centred on the bill and coin modules. In fact, the bill and coin module calls represented about two-thirds of the reason for all road calls. The causes that resulted in the majority of problems were mechanical or electrical based (40 percent), passenger error (21 percent) and bill or coin jams (19 percent). These causes have remained as the eighty percent contributors to road calls, even though the weekly number of road calls has dropped to between 25 and 35. About 40 percent of problem bill modules and about 60 percent of problem coin modules are replaced on the road by inspectors. The number of buses pulled off the road by inspectors because of inoperable fareboxes averaged around four buses per week toward the end of the analysis period.

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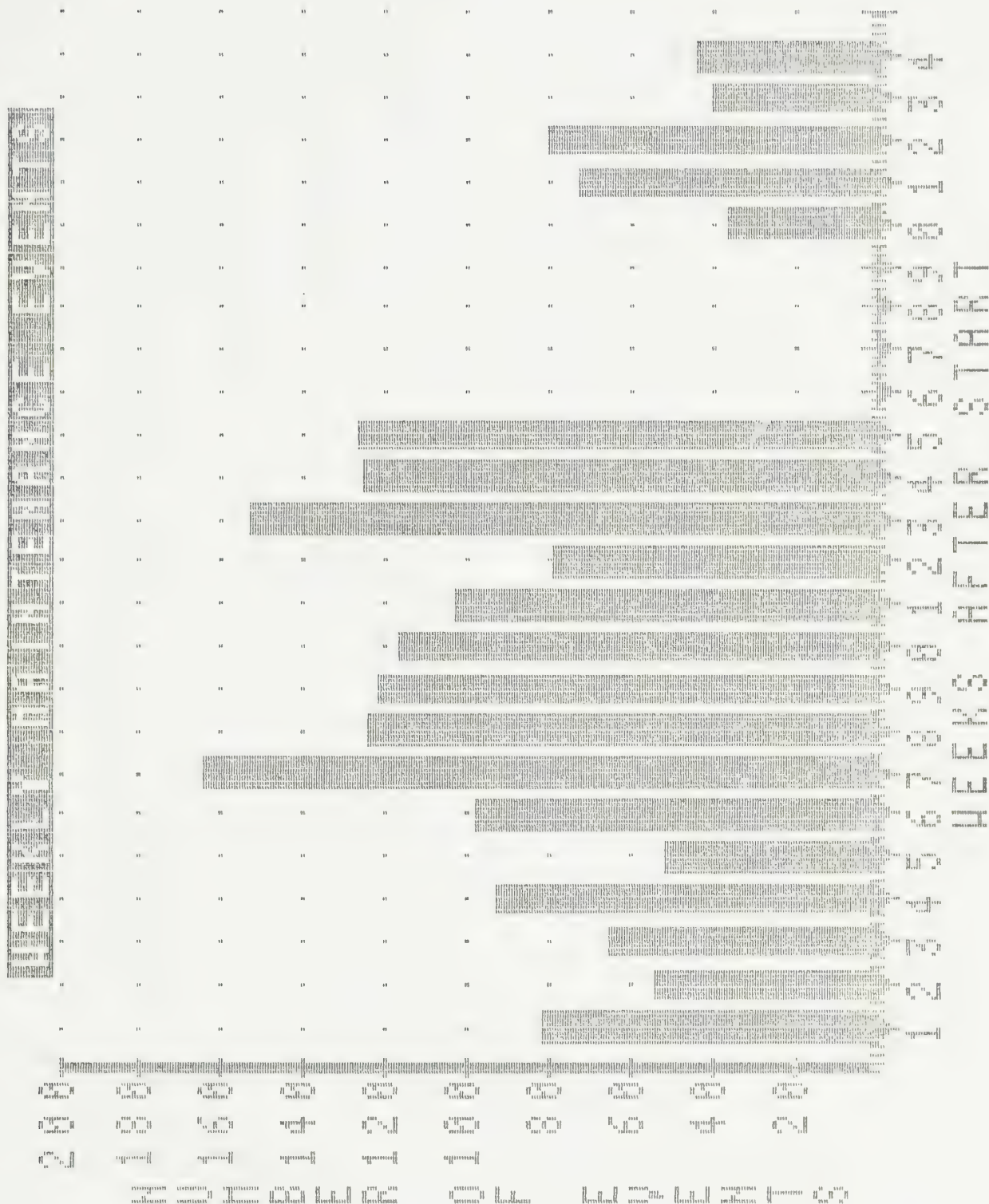
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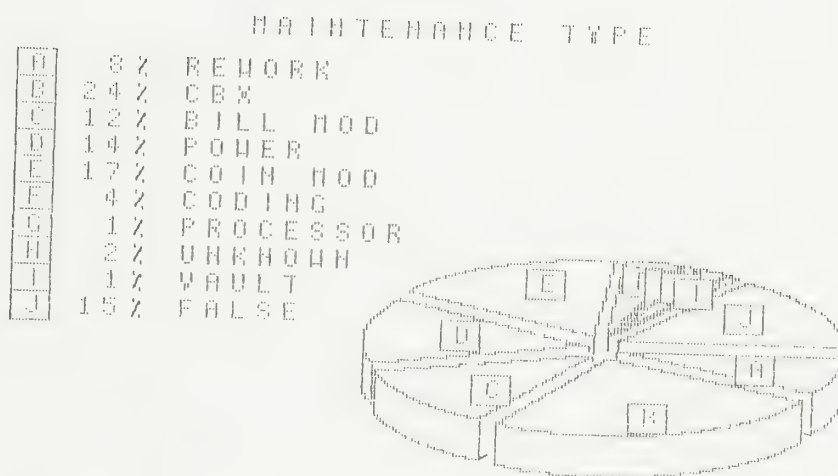
3.0 ASSESSMENT OF MAINTENANCE RECORDS

The farebox supplier provided all maintenance services for the farebox except for preventive maintenance. Records were kept for each maintenance event and the record included such items as date of repair, bus number, symptoms of malfunction, action taken, repair action and repair time. A set of codes was developed by the supplier to standardize the reporting of the symptoms of the farebox malfunction. Over 1500 maintenance records were examined for the first 15 week period used in the maintenance assessment, and about 270 maintenance records were examined for week 20 through week 24.

3.1 Frequency and Type of Maintenance Events

The frequency of weekly maintenance events is shown in Figure 1. The chart shows that the number of weekly maintenance events was low over the first six weeks of operation when compared to the last nine weeks in the first 15 week assessment period. The overall average of 103 maintenance events weekly over the first 15 weeks was exceeded in seven of the final nine weeks. In the 20th to 24th week, the average number of weekly maintenance events was reduced to 54. The second chart, Figure 2, shows the type of maintenance carried out over the 15 week assessment period. The chart shows that 24 percent of the maintenance events involved the cashbox (CBX). Most of the CBX problems were related to overfilling or problems with opening the vault at the garage. The next highest percentage of maintenance events are coin module problems (17 percent),





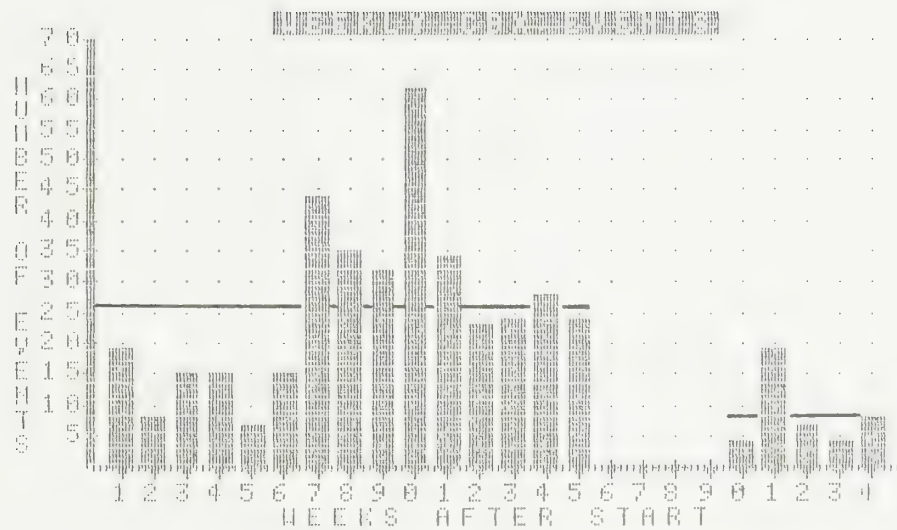
Type of Maintenance Performed

Figure 2

power supply problems (14 percent) and bill module problems (12 percent). Coin module problems were largely the result of dirt and oil buildup on the sensors, causing misreads and other problems. Power supply problems centre on a variety of events including power failure, backlight re-installation, broken resistors due to handling, and loose connections due to road surface conditions. One major cause of maintenance investigations was "false alarms". False alarms occurred when malfunctions were reported from the field and it was found, upon testing, that the claimed malfunction was not present in the farebox. A variety of other problems existed, but at a low contributory rate.

3.2 Cashbox Maintenance

Figure 3 shows the history of cashbox maintenance. For the first six weeks, the incidence of maintenance was low and usually focused on assistance in closing the vault or problems related to overfill of bills. During the middle five weeks (week 7 through week 11) the problems revolved around a failure to probe, that is a failure to open the locking system to release the cash vault. This problem required some internal retrofitting of the guides and is now largely complete. The incidence of cashbox maintenance over the last four weeks of the of the first 15 weeks assessment is down to about twenty five events weekly. Further adjustments were carried out on the vaults during weeks 16 through 19, and the maintenance records for weeks 20 through 24 were then examined. It was found that the final adjustment to the vault resulted in an average of eight maintenance events per week on the cashbox. The frequency of maintenance events for the cashbox will likely remain at this level.



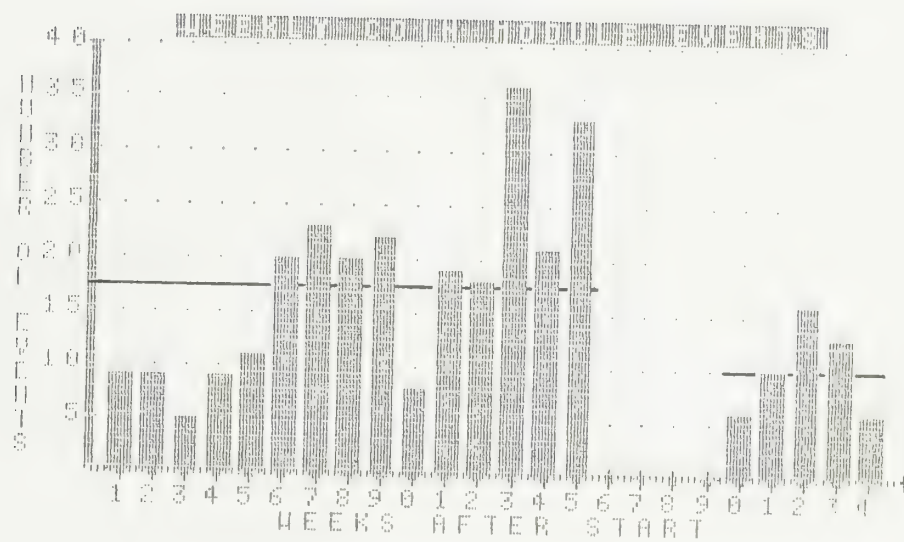
Number of Weekly Cashbox Repairs
Weeks 1 through 15
and 20 through 24

3.3 Coin Module Maintenance

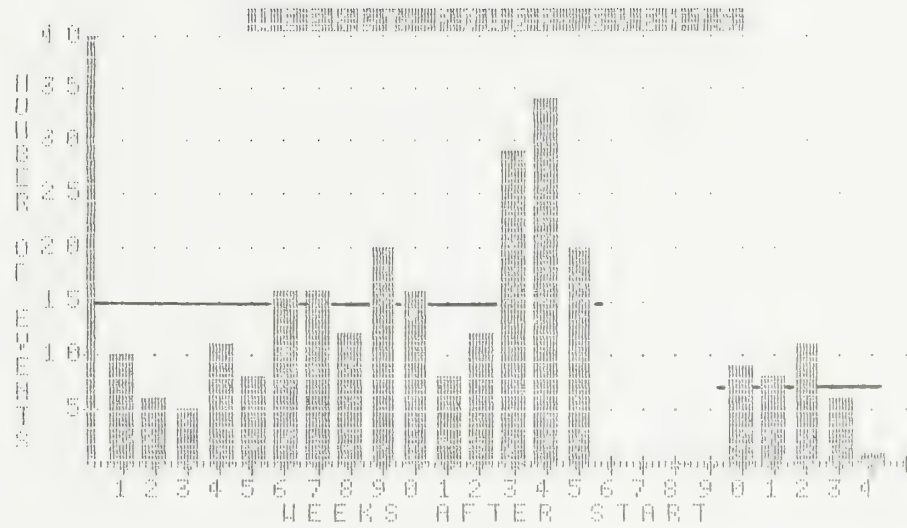
The number of events for coin module maintenance on a weekly basis is shown in Figure 4. The figure shows a steady rise in weekly maintenance requirements for the coin module from an average, over the first five weeks of nine events weekly, to an average of 30 per week through the week 13 through week 15 period. This trend can be largely identified as a lack of proper preventive maintenance. The maintenance records for coin module maintenance work over the week 13 through week 15 period cited dirty sensors as the main factor for coin modules being sent in for "coin misreads". An improvement in the preventive maintenance work has been achieved, and this is reflected in the maintenance records of weeks 20 through 24. On this basis, the continuing coin module maintenance work (on a weekly basis) should stabilize at around 10.

3.4 Power Item Maintenance

The number of power related items requiring maintenance is shown in Figure 5. The incidence of maintenance work has risen from the first weeks (average less than 10 incidents) to an average of almost 28 incidents per week at the end of the first 15 week period. The rise is attributed to a rash of broken resistors, likely due to the manner in which the modules are carried, and a number of loose connections. The resistor problem can likely be resolved by training, and the loose connection problem, which is a function of road surface condition, may be moderated by preventive maintenance. The maintenance records for weeks 20 through 24 verified the reduction anticipated in weekly power maintenance events. The average weekly power maintenance events during week 20 through week 24 is 7.



Number of Weekly Coin Module Repairs
Weeks 1 through 15
and 20 through 24



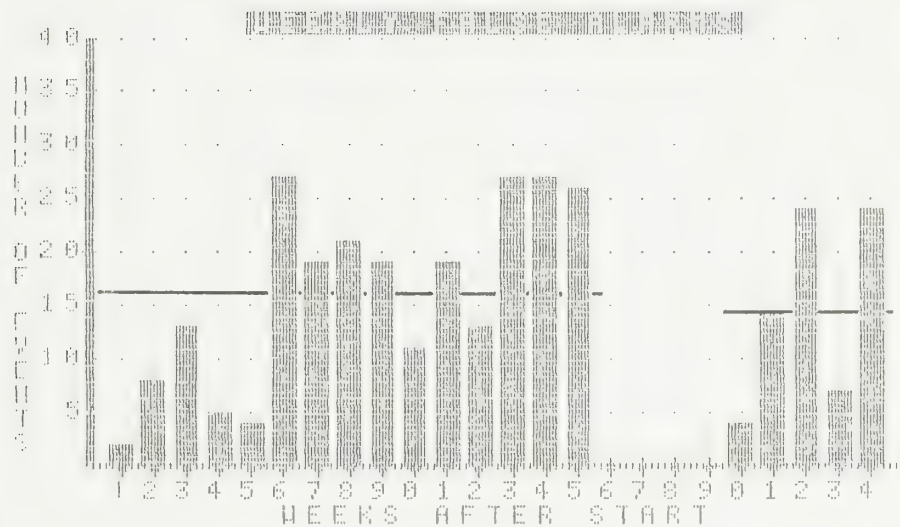
Number of Weekly Power Related Repairs
Weeks 1 through 15
and 20 through 24

3.5 False Alarms

The incidence of false alarms has risen on a weekly basis from six in the beginning of the test period to 27 by week 13 through 15. This is shown in Figure 6. The reason for the increase in false alarms is difficult to understand. It would have been normal to have anticipated that as the inspectors and drivers became more familiar with the new fareboxes that the incidence of inaccurate malfunction reporting would drop. A review of the maintenance records for weeks 20 through 24 showed that the incidence of false alarms dropped to 15 events weekly, although there was a wide variation in the number of weekly false alarms. Perhaps as the HSR takes over more of its own farebox maintenance, average weekly incidence of 15 events will be maintained.

3.6 Time Required for Maintenance

Table 2 shows the amount of time spent on maintenance on a weekly basis, as well as the average maintenance time per maintenance type. Recorded maintenance time averaged about 27 hours per week over the first six weeks of farebox use. Over the last three weeks in the test period, the average weekly maintenance effort averaged 95 hours. The contract with the supplier allows for 100 hours of maintenance weekly, and does not cover preventive maintenance or warranty work done at the suppliers shop. The mean repair time for almost any maintenance item is around 30 minutes, with the exception of repairs to the main vault, which is substantially higher. It should also be noted that between one-third and one-quarter of the reported repair time was spent in searching through the garage for the bus within which the reported farebox was located. Although the average



Number of Weekly False Alarm Repairs
Weeks 1 through 15
and 20 through 24

Table 2

HSR MAINTENANCE RECORDS

NUMBER OF INCIDENTS REQUIRING MAINTENANCE EFFORT

REPAIR CODE	MARCH16 MARCH22	MARCH23 MARCH29	MARCH30 APRIL5	APRIL6 APRIL12	APRIL13 APRIL19	APRIL20 APRIL26	APRIL27 MAY3	MAY4 MAY10	MAY11 MAY17	MAY18 MAY24	MAY25 MAY31	JUNE1 JUNE7	JUNE8 JUNE14	JUNE15 JUNE21	JUNE22 JUNE28	ROW TOTAL	MEAN INCID
0 REMORK	1	3	12	23	2	1	29	18	14	9	8	1	6	0	0	127	8
1 CBX	19	8	15	15	7	15	44	35	32	62	34	23	24	28	24	385	26
2 BILL MODULE	16	8	13	22	17	14	23	13	11	3	3	4	19	18	11	185	12
3 POWER	10	6	5	11	8	16	16	12	20	16	8	12	29	34	20	223	15
4 COIN MODULE	9	9	5	9	11	20	23	20	22	8	19	18	36	21	33	263	18
5 CODING ERROR	24	11	1	5	0	1	1	2	2	3	2	4	0	3	2	61	4
6 PROCESSOR	0	1	0	1	0	2	1	1	0	0	3	2	4	1	2	18	1
7 UNKNOWN	0	0	1	1	1	2	4	0	1	1	5	1	7	2	6	32	2
8 MAIN VAULT	0	0	0	0	1	0	4	2	0	3	1	1	1	1	2	16	1
9 FALSE ALARM	2	8	13	5	4	27	19	21	19	11	19	13	27	27	26	241	16
TOTAL INCIDENTS	81	54	65	92	51	98	164	124	121	116	102	79	153	125	126	1551	103

MAINTENANCE EFFORT IN MINUTES

	MEAN REPAIR															
0 REMORK	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1 CBX	540	235	347	510	135	405	1390	1075	1170	1970	1600	870	905	1245	1260	13657
2 BILL MODULE	480	315	218	635	410	265	570	295	295	95	90	165	865	525	420	5643
3 POWER	330	270	73	260	240	350	335	305	520	570	285	300	1130	1515	1035	7608
4 COIN MODULE	250	225	150	220	20	425	515	625	665	265	675	615	1400	1035	1485	8570
5 CODING ERROR	555	285	15	120	0	10	15	40	50	90	100	120	0	90	60	1550
6 PROCESSOR	0	15	0	45	0	55	50	45	0	0	130	60	180	45	60	685
7 UNKNOWN	0	0	15	15	15	45	155	0	45	30	165	30	240	60	285	1100
8 MAIN VAULT	0	0	0	0	105	0	225	390	0	180	210	30	150	30	240	1560
9 FALSE ALARM	45	225	210	120	80	500	305	460	555	330	620	390	950	1040	930	6760
TOTAL MINUTES	2200	1570	1028	1925	1005	2055	3560	3235	3300	3530	3875	2670	5820	5585	5775	47133

TABLE 2 CONTINUED

TEST MAINTENANCE REPORTS

NUMBER OF INCIDENTS REQUIRING MAINTENANCE EFFORT

REPAIR (Y00)		JUL 27 AUG 2	AUG 3 AUG 9	AUG 10 AUG 16	AUG 17 AUG 23	AUG 24 AUG 30
0 REMARK		0	1	0	0	0
1 CBX		4	19	7	4	8
2 BILL VAULT		8	7	9	4	1
3 POWER		9	8	11	6	1
4 COIN MODULE		6	10	16	13	6
5 CODING ERROR		3	8	5	1	1
6 PROCESSOR		0	2	4	4	1
7 UNKNOWN		2	1	3	0	1
8 MAIN VAULT		0	2	1	0	0
9 FALSE ALARMS		4	14	24	7	24
TOTAL INCIDENTS		36	72	80	39	43

number of weekly maintenance events over the first 15 weeks was 103, the average number of weekly maintenance events during week 20 through week 24 was only 54. This was a result of the final adjustment to the cashbox vault as well as the improved preventive maintenance program.

3.7 Prognosis

Although the maintenance records for the first 15 weeks paint a poor picture, enough maintenance issues and "one time" problems have been resolved or improved to the point that some normalcy has returned to the maintenance function. The list below shows the expected number of maintenance events, by type, that can now be expected after the examination of records through week 24.

Cashbox	8-10 per week
Bill module	6- 8 per week
Power	7-10 per week
Coin module	10 per week
Coding errors	2 per week
Processors	2 per week
Unkown	2 per week
Main vault	1 per week
False Alarms	15 per week
Total	53-60 per week

This estimated weekly maintenance requirement for the fareboxes suggests that there will be between 29 and 33 hours of maintenance weekly. This does not include preventive maintenance time nor does it deal with manning the maintenance function between the two garages. The 53 to 60 weekly maintenance events translate to 11 or 12 maintenance events per bus per year.

4.0 FARE EVASION

The fare evasion question was addressed by conducting a before and after study to determine whether there was a statistically significant difference in expected revenue per \$100 using the old fareboxes when compared to using the new fareboxes. In this fare evasion test the measure of fare evasion was the difference between actual and calculated revenue per \$100 of expected revenue.

4.1 The Before and After Sample

The data collected in the before and after tests was aimed at identifying how much revenue was deposited in the farebox on the one hand, and how much revenue should have been deposited in the farebox on the other hand. This was accomplished by putting checkers on selected bus runs. The checkers undertook passenger classification counts of the observed cash fare passengers. The checkers took up a position near the front of the bus and recorded the classification information as passengers boarded the bus and paid their fares. Each of these data collection efforts began with an empty cash vault on the farebox. At the end of each data collection exercise (a two hour to a five hour duration), an inspector would come and remove the vault, take it to the cash room and the cash contents would be counted.

The routes were selected by HSR research on the basis of their overall route sampling plan. The routes selected represented a mix of mountain and lower city routes. The samples also varied by time of day and day of the week. The before sampling represented 60 data points collected between February 9, 1987 and February 27, 1987 and covering almost 3700 cash passengers. The after sample represented 51 data points collected between April 15, 1987 and May 13, 1987. The "after" data collection was not initiated until the new fareboxes had been in operation for a full month. The data points in the after sample generally replicated those collected in the before sample in terms of routes, days and time periods, as shown below:

<u>Day</u>	<u>Before Samples</u>	<u>After Samples</u>
Monday	11	9
Tuesday	12	10
Wednesday	11	18
Thursday	12	12
Friday	14	2
<u>Period</u>		
A.M.	18	15
Mid-day	27	24
P.M.	15	12
<u>Route</u>		
1	3	3
2	4	3
4	7	6
5	23	25
11	4	3
21	4	2
22	5	3
25	5	2
41	5	4

4.2 Data Summary

The data collected was reduced to a form where a difference in the means test could be run. The test statistic was the difference between anticipated and actual revenue per \$100 of expected revenue. This statistic was calculated for each data point, 60 before points and 51 after points. It was calculated by subtracting the revenue expected to be in the farebox based on the cash passenger classification count from the actual amount of cash in the farebox and was normalized to the \$100 base using the expected revenue calculated from cash passenger classification. From this data, a mean value of difference in revenue per \$100 could be calculated for the before and after data. This is summarized below in Table 3.

Table 3

Before and After Study Results

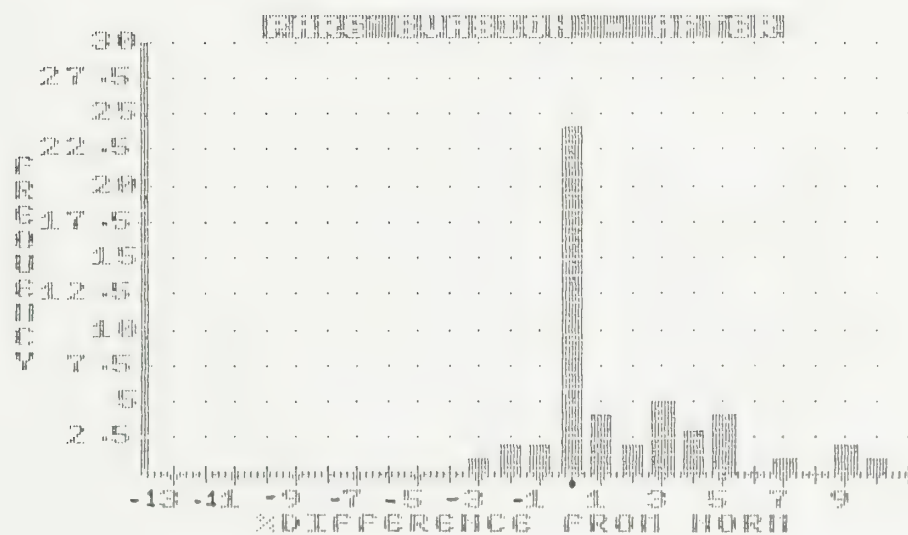
Data	Mean (diff/\$100)	Standard Deviation	Sample Size
Before	- 0.42	3.55	60
After	+ 1.60	2.82	51

For the before study, the difference in revenue between what was in the farebox and what should have been in the farebox for every \$100 of expected farebox revenue was a shortfall of 42 cents. For the after study, the difference in revenue between what was in farebox and what should have been in the farebox for every \$100 of expected farebox revenue was a surplus of \$1.60.

A review of Figure 7 shows why there is a difference in the before and after data. The distribution of differences from the norm (difference per \$100 of expected revenue) in the before data shows that there were about the same frequency of data points representing under payment of fares as overpayments. However, in the after study, there were hardly any underpayments. There was a relatively high frequency of correct payments and a certain level of overpayments that generally mirrored the before study overpayment distribution. In short, the new fareboxes appeared to stop the underpayment of fares.

4.3 Conclusions

The data was tested using a "difference of the means" test. The difference of the means was \$2.02 per \$100 of expected revenue. The standard deviation of the "difference of the means" was \$0.60 difference per \$100 expected revenue. This yields a test statistic of 3.37 ($2.02 \div 0.6$) and infers that the difference in the means is significant at the 99 percent level. The conclusion drawn, with a high level of statistical accuracy, is that the amount of fare collected due to the new farebox has increased by two percent. The actual increase may be a little higher due to biases in the data collection which may have resulted in the before passengers tending to pay the correct fares because of the presence of survey personnel observing the fare drops.



Distribution of Percent Variation from Expected Revenue
Before and After New Farebox Installation

5.0 DRIVERS SURVEY

A driver survey was run to test driver reaction to the new fareboxes. The survey form was developed and circulated within the administrative section of the HSR, and modified. The survey was handed out to all drivers beginning their shifts at either the Wentworth or Mountain Garages on June 3, 1987. This did not represent 100 percent of HSR drivers since not all drivers work every day and not all drivers start or end their shifts at either garage. The survey covered 204 drivers, or about a 40 percent sample.

The questionnaire contained 17 questions including two areas for driver comment. The questions dealt with the performance of the new fareboxes, the quality of training received and comparisons with the old fareboxes. In addition, over 275 comments were recorded by the drivers concerning the fareboxes and the training.

5.1 Questionnaire Responses

The responses to the questionnaire have been summarized in Table 4. This table is a general reproduction of the questionnaire, with some of the questions being aggregated to form more complete answers. The accuracy level varies for each response, however, in general, the responses are accurate to at least plus or minus six percentage points. The accuracy level is a function of sample size and percentage of response type in each category. The survey was taken by 204 drivers with an average of 14.6 years driving experience.

Table 4

HSR DRIVER SURVEY RESULTS

NUMBER OF DRIVERS COMPLETING SURVEY 204

AVERAGE YEARS DRIVING EXPERIENCE 14.6

HOW MANY FARE JAMS DID YOU HAVE
ON YOUR LAST SHIFT AND HOW WERE THEY CAUSED

NUMBER	FREQUENCY OF JAMS	DUE TO BILLS	DUE TO COINS
184	0	0	0
9	1	6	3
5	2	6	4
1	3	2	1
3	5	5	10

IS THE VISIBILITY OF THE FARE INSPECTION AREA:

Easy to see all the time	158
Easy to see in the daytime only	38
Difficult to see	6

IS THE VISIBILITY OF THE DRIVER INFO LINE:

Easy to see all the time	83
Easy to see some of the time	83
Difficult to see	36

DO YOU FIND THE "B2" LOG ON PROCEDURE:

Easy to do	197
Somewhat difficult to do	3
Difficult to do	2

DO YOU FIND THE "B3" CHECK THAT YOU PERFORM:

Easy to do	196
Somewhat easy to do	5
Difficult to do	1

Table 4 (continued)

DID YOU FIND THAT THE BOOKLET "ELECTRONIC FAREBOX
TIPS FOR OPERATIONS" WAS:

Very helpful	117
Somewhat helpful	72
Not very helpful	6

WAS THE TRAINING THAT YOU RECEIVED ON THE NEW FAREBOX:

Very good	131
Good	61
Fair	10
Bad	0
Very bad	0

IN TERMS OF THE NUMBER OF FARE DISPUTES AND IN TERMS
OF HOW PASSENGERS REACT TO FARE CHALLENGES:

Number of Disputes?	Do passengers accept the fare shown?			
	Yes	No	No comm.	Total
Increase	9	1	0	10
No change	24	5	0	29
Decrease	149	9	4	162
Total	182	15	4	

WHAT IS YOUR OVERALL IMPRESSION OF THE NEW FAREBOX?

Very good	88
Good	83
Fair	22
Poor	7

WHAT IS YOUR IMPRESSION WF THE NEW FAREBOX
WHEN IT IS COMPARED TO THE OLD FAREBOX?

The new farebox is much better	166
slightly better	31
slightly worse	2
much worse	2

The drivers were asked how many fare jams were experienced on their last shift. 184 drivers (91%) experienced no fare jams during their most recent shift. Nine drivers experienced one fare jam and nine other drivers experienced between two and five fare jams. The fare jams were evenly split between the bill module and the coin module.

A series of questions were asked relating to operational characteristics of the farebox. These operational matters are largely of importance only to the drivers, but are central to the functioning of the farebox. 158 drivers (78%) said that the visibility of the fare inspection area was "easy to see at all times", 38 drivers said that it was easy to see in daytime only and only six drivers (3%) said the fare inspection area was difficult to see. When asked about the visibility of the drivers information line, the response was quite different. The drivers information line is a small LED display on the back of the farebox that the driver uses for log-on and system checkout purposes. 83 drivers (41%) said that the visibility of the driver information line made it easy to use all the time. Another 41 percent said that it was only easy to see (and read) some of the time, while 18 percent of the drivers said it was difficult to see. The problem with the visibility of the driver info line was determined to be that backlighting for the LED was not operational on all fareboxes. Since this survey was run, maintenance personnel have installed the backlighting on the driver information line of all boxes. Two other questions regarding driver operation were asked. These questions related to the ease with which drivers could "log-on" (B2) and run through the farebox check (B3). In both cases, the overwhelming majority of drivers (97%) stated that the B2 and B3 functions were easy to do.

Next, there were two questions regarding the training program given to the drivers. 131 drivers (65%) said their training was very good and 61 drivers (30%) said their training was good. As part of the training exercise, a small booklet, developed by the HSR, was given to each driver. 117 drivers (60%) said the booklet was very helpful and only six drivers (3%) said the booklet was "not very helpful".

A key question asked of the drivers related to the number of fare disputes that were occurring with the new fareboxes and whether the self registering fare feature was making fare disputes easier to resolve. First, 162 drivers (81%) said that with the new farebox there was a decrease in the number of fare disputes over the old fareboxes, 29 drivers (14%) said there was no change and a few drivers (10) said there was an increase in the fare disputes. 182 drivers (91%) said that the passengers seemed to accept the fare shown by the new fareboxes as correct and 15 drivers (7%) thought that passengers did not accept the fare shown as correct.

The last questions asked related to what the drivers thought of the new fareboxes. 88 drivers (44%) overall impression of the new fareboxes was very good, 83 drivers (42%) overall impression of the new farebox was good and only seven drivers (3%) overall impression of the farebox was poor. When the drivers were asked their impression of the new fareboxes when compared to the old fareboxes, 166 drivers (83%) said the new fareboxes were much better than the old fareboxes and only four drivers (2%) rated the new fareboxes worse than the old fareboxes.

5.2 Driver Comments

The drivers commented on various aspects of the farebox and the training they received. The comments are summarized and are contained in the Appendix. The comments either amplified on the questions in the questionnaire or they broke new ground on some issues. In brief, most of the comments were about the difficulty or time required for the farebox to accept bills. In fact, several of the drivers comments were directed at design solutions to the bill insertion problem. There were a variety of comments on farebox operations, and the main comment regarding the need to backlight the LED driver display line has since been corrected by maintenance. There were comments about the coin module and its problems of generating misreads. These comments, combined with others, have led to an awareness of the need for improved preventive maintenance of the coin sensors. There were also a significant number of laudatory messages relating to the acquisition of the new fareboxes.

5.3 Conclusions

Conclusions drawn from the driver survey are quite positive and can be summarized as follows:

- * 85 percent of drivers had a good or very good impression of the new farebox
- * 83 percent of drivers think that the new farebox is much better than the old farebox

- * 81 percent of the drivers claimed that they experienced a decrease in the number of fare disputes with the new fareboxes
- * 91 percent of the drivers said that the passengers accept the fare shown on the new fareboxes as correct
- * 91 percent of the drivers said they did not experience any fare jams on their previous shift
- * an overwhelming proportion of the drivers found the fareboxes easy to use in terms of log-on and system checkout
- * a number of drivers commented on problems associated with bill insertion into the new farebox.

6.0 BOARDING TIME ANALYSIS

A boarding time analysis was undertaken to determine what the boarding times were for the new fareboxes. The analysis was also in response to comments from some drivers that increased boarding time was leading to difficulty with schedule adherence on heavily loaded lower city routes.

6.1 Boarding Time Survey

After the driver surveys were received and reviewed, a boarding time survey was initiated. The survey was run during the middle of June. Survey personnel were placed on buses and recorded cash passengers, pass passengers and boarding time at each stop. The boarding time was recorded from the time the first boarding passenger stepped onto the bus until the door closed and the bus pulled out. The data used for this analysis all came from Route 1, the King Route. Because of the manner in which the data was collected and the need to break out boarding time for cash passengers as opposed to pass passengers, a multiple regression analysis was undertaken to isolate boarding times. The regression equation developed from the data was:

$$T = 4.21 c + 3.07 p + 0.27$$

where T = total boarding time in seconds
 c = cash passengers
 p = pass passengers

The regression coefficient R^2 was 0.98, suggesting a good fit of the data.

The regression equation suggests that the boarding time for a cash passenger is about 4.2 seconds and the boarding time for a pass passenger is about 3.1 seconds. Although both boarding times seem a little higher than the "industry average", it is important to note that the cash passenger boarding time is only 1.1 seconds longer than the pass passenger boarding time. This is significant because at the time of the survey, the pass passengers only had to flash their pass while boarding the bus. In addition, with the advent of the one collar coin, fewer bills will probably be used as fare medium in the future. This will tend to speed boarding time.

7.0 FAREBOX PERFORMANCE COMPARISON: ACTUAL VS ANTICIPATED

This chapter compares the actual performance of the farebox to the performance anticipated by the HSR prior to the acquisition of the new fareboxes. The anticipated performance levels for the farebox were outlined in a letter to the Transit Office of the MTC dated March 4, 1986. The anticipated and actual performance comparisons are shown below.

7.1 Farebox Jamming

It was anticipated that the new fareboxes would eliminate jamming because of the coin and bill acceptance mechanisms and because of motors activated by drivers which could alleviate jams if they occurred.

The driver survey asked how many drivers had experienced fare jams on their previous shift. Ninety one percent of the drivers claimed that they experienced no fare jams. In addition, most fare jams that did occur (the remaining nine percent) were resolved with the module motors. Road Call Reports, which largely relate to unresolvable fare jams, are running about 25 per week or about three and one half per day.

The actual performance appears to have met the HSR expectation in regard to farebox jams.

7.2 Reduction in Fare Disputes

It was anticipated by the HSR that the new fareboxes would be able to address the problem of fare disputes with passengers. The problem with the old fareboxes was that drivers had little basis for challenging a passenger because he would have to count the fare. The other situation involved the use of half dollar bills by some passengers instead of the proper fare.

The Driver Survey dealt with the question of fare disputes. Eighty one percent of the drivers claimed that there was a decrease in the number of fare disputes with the new fareboxes and fourteen percent said there was no change. Ninety one percent of the drivers said that passengers accepted the fare shown by the farebox.

The actual performance of the farebox appears to have met the HSR expectation in regard to reducing and resolving fare disputes.

7.3 Passenger Boarding Times

The HSR anticipated that there would be no change in boarding time because of the new fareboxes.

The Boarding Time Analysis was not a before and after study. However, the average boarding time for a cash passenger was calculated to be about 4.2 seconds, or about one second longer than the average boarding time for a pass passenger. The industry standard boarding time for a multiple-coin cash fare is between 3.0 and 4.0 seconds. Therefore, the new boarding times tend to be on the high side. In addition, drivers have commented that the dollar bills are slow to process and sometimes the longer boarding times affect schedule adherence on the lower city routes.

The actual performance of the farebox appears to be at variance with the anticipated performance in this case. It should be remembered that the introduction of the dollar coin should have the effect of reducing average boarding times for cash fares.

7.4 Farebox Repair Frequency

It was anticipated that the HSR would experience 12 farebox repairs per bus per year with the new farebox. Taking the weekly anticipated repair level described in section 3.7 of 53 to 60 farebox repairs per week, a level of 11 to 12 farebox repairs per bus per year could be expected. This includes an allowance of about three farebox repairs per bus per year for false alarms.

This projected performance is exactly the maintenance level anticipated by the HSR at the time of aquisition of the system.

7.5 Farebox Maintenance Hours

The anticipated number of maintenance hours for farebox repair (exclusive of preventive maintenance) was estimated to be 1960 annual hours. The actual number of annual maintenance hours projected from the maintenance records is between 1510 and 1720 annual hours.

The projected annual maintenance hours are between 240 and 450 hours lower than the anticipated number of annual maintenance hours. However, the question of efficiently scheduling the annual maintenance between two garages must still be answered, and may add to the maintenance time.

7.6 Road Calls

There was no anticipated road call figure outlined as a target by the HSR. However, an analysis of the Road Call Reports experienced with the new farebox suggested that an average of about five calls per bus per year across the entire fleet can be expected.

7.7 Fare Evasion

The anticipated reduction of fare evasion brought about by the new fareboxes was thought to result in an increase in revenue of about four (4) percent. The actual increase in revenue brought about by the new fareboxes was two (2) percent. The two percent figure must be tempered by possible biases in the data collection methodology (unavoidable) and by the remarkable distribution of revenue achieved by the new fareboxes which show an overall overpayment of fares.

The anticipated revenue make up from fare evasion was not as large as the actual case has proved.

7.8 Driver Acceptance

The HSR anticipated good driver acceptance of the farebox. Eight six percent of the drivers had either a good or very good impression of the new farebox. Eighty three percent of the drivers said that the new fareboxes were much better than the old fareboxes.

The acceptance of the new fareboxes by the drivers met the HSR expectation.

8.0 CONCLUSION

The anticipated outcome of the performance of the new fareboxes by the HSR was met or nearly met in the case of minimal fare jams requiring non-driver resolution, reduced fare disputes with customers, passenger boarding time, driver acceptance and maintenance effort.

The anticipated revenue increase of four percent due to a reduction in fare evasion turned out to be a two percent increase.

On balance, after overcoming some early "learning curve" problems and one time maintenance events, it can be concluded that the new electronic self registering fareboxes met or nearly met all the targets established for it in the evaluation phase of farebox selection.

APPENDIX

COMMENTS ON THE FAREBOX FROM THE DRIVERS

There were over 200 comments received about the fareboxes from the drivers on the HSR Driver Survey. The driver comments are important because they provide a "front line" perspective on various aspects of the farebox performance. The comments have been grouped into six categories as follows:

- Bills
- Operations
- Laudatory comments
- Coins
- Reliability
- Farebox Positioning

Bills - 92 comments

- Bills are difficult to insert because the slot is too narrow or the angle of insertion is too flat (43 comments)
- Bills are too slow to load into the farebox and result in running time delays (30 comments)
- Bills that are old or damp are very difficult for passengers to use (19 comments)

Operations - 40 comments

- Lights are necessary to illuminate the driver information line. Otherwise it is too difficult to read (22 comments)
- There is a danger of passengers fingertips being caught in the bill and ticket slot (6 comments)
- Drivers require a longer "Hold" time before the fare is dropped into the vault (4 comments)
- It is difficult to record large numbers of child passengers boarding at a stop (3 comments)
- Drivers wish that the farebox could also issue transfers (2 comments)
- The power supply to the boxes should not be shut off when the bus is shot down at the end of a run (2 comments)
- It is difficult to see the belt moving in the bill module (1 comment)

Laudatory Messages - 32 comments

- These comments were of a positive nature relating to the new farebox or managements decision to aquire them (32 comments)

Coins - 21 comments

- Coins are not always properly counted. Often dimes go through the sensors stuck together or dimes and pennies are interchanged in the counting process (21 comments)

Reliability - 13 comments

- The failure rates are too high (7 comments)
- There is a need for better preventive maintenance (6 comments)

Location and Position - 3 comments

- The base of the farebox should be mounted a few inches off the floor of the bus because of the slush and salt conditions in the winter (2 comments)
- The farebox is located too close to the driver (1 comment)

COMMENTS ON FAREBOX TRAINING

- Use a variety of real bills (old, damp etc) and demonstrate the proper bill insertion method (9 comments)
- Use more "case study" techniques including actual road problems such as fare jams, handling combined fares and handling common mistakes (8 comments)
- Allow for more "hands on" time during training (11 comments)
- Improve the quality of information available from the trainers (3 comments)
- The training was satisfactory (45 comments)

